



## Marine climate and hydrography of the Coralline Crag (early Pliocene, UK): isotopic evidence from 16 benthic invertebrate taxa

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### ABSTRACT

The taxonomic composition of the biota of the Coralline Crag Formation (early Pliocene, eastern England) provides conflicting evidence of seawater temperature during deposition, some taxa indicating cool temperate conditions by analogy with modern representatives or relatives, others warm temperate to subtropical/tropical conditions. Previous isotopic ( $\delta^{18}\text{O}$ ) evidence of seasonal seafloor temperatures from serial ontogenetic sampling of bivalve mollusk shells indicated cool temperate winter ( $< 10^\circ\text{C}$ ) and/or summer ( $< 20^\circ\text{C}$ ) conditions but was limited to nine profiles from two species, one ranging into and one occurring exclusively in cool temperate settings at present. We supplement these results with six further profiles from the species concerned and supply seven more from three other taxa (two supposedly indicative of warm waters) to provide an expanded and more balanced database. We also supply isotopic temperature estimates from 81 spot and whole-shell samples from these five taxa and 11 others, encompassing ‘warm’, ‘cool’ and ‘eurhythmic’ forms by analogy with modern representatives or relatives. Preservation tests show no shell alteration. Subject to reasonable assumptions about water  $\delta^{18}\text{O}$ , the shell  $\delta^{18}\text{O}$  data either strongly indicate or are at least consistent with cool temperate seafloor conditions. The subtropical/tropical conditions suggested by the presence of the bryozoan *Metrarabdotos* did not exist. Microgrowth-increment and  $\delta^{13}\text{C}$  evidence indicate summer water-column stratification during deposition of the Ramsholt Member, unlike in the adjacent southern North Sea at present (well mixed due to shallow depth and strong tidal currents). Summer maximum surface temperature was probably about  $5^\circ\text{C}$  above seafloor temperature and thus often slightly higher than now ( $17\text{--}19^\circ\text{C}$  rather than  $16\text{--}17^\circ\text{C}$ ), but only sometimes in the warm temperate range. Winter minimum surface temperature was below  $10^\circ\text{C}$  and possibly the same as at present ( $6\text{--}7^\circ\text{C}$ ). An expanded surface temperature range compared to now may reflect withdrawal of oceanic heat supply in conjunction with higher global temperature.

### 1. Introduction

The Coralline Crag Formation is an early Pliocene marine unit up to 20 m thick occurring in Suffolk, East Anglia, eastern England. Although actual exposures are fairly limited in number, it has an almost continuous onshore outcrop stretching some 25 km south-west from the coastal town of Aldeburgh (Fig. 1), and extends 14 km north-east from there under the southern North Sea (Balson, 1992). Outliers at Ramsholt, Sutton Knoll (also known as Rockhall Wood) and Tattingstone

(now submerged beneath a reservoir) extend the area of occurrence of the formation 27 km west-south-west of the main onshore outcrop. The unit is typically a fine–medium sand, strongly bioturbated and with a mud admixture of up to 24% in the Ramsholt Member, but generally less bioturbated and with a lower mud content in the overlying Sudbourne and Aldeburgh members (Balson et al., 1993); the calcium carbonate content is high throughout (usually 60–70%; Balson et al., 1993). Unconformably below and above the Coralline Crag are more extensive marine units with a much lower calcium carbonate content:

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